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NATURAL REGENERATION IN THE WESTERN WHITE PINE TYPE

NORTHERN ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

MISSOULA, MONTANA

NATURAL REGENERATION

IN THE WESTERN WHITE PINE TYPE

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Foreword

A long-felt need for a comprehensive publication on western white pine silviculture has been filled by preparation of a manuscript "Natural Regeneration in the Western White Pine Type," bringing together information on the subject gained from 25 years of forest research and 30 years of National Forest timber cutting practice.

Pending publication of the entire manuscript, the attached summary has been prepared for limited distribution to make the main findings immediately available.

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NATURAL REGENERATION IN THE WESTERN WHITE PINE TYPE

THE WESTERN WHITE PINE TYPE

The western white pine type of northern Idaho and nearby portions of Washington, Montana, and British Columbia is composed of western white pine, western red cedar, western larch, Douglas fir, lowland white fir, and western hemlock as principal associates with Engelmann spruce, alpine fir, lodgepole pine, and ponderosa pine as minor components. The region within which the western white pine type is the principal forest cover in shown in figure 1. The associated species differ widely in their requirements, and in combination with the mountainous topography characteristic of the region, produce a forest of great silvical diversity. Composition of the type, defined as consisting of 15 percent or more western white pine by volume, varies from almost pure pine to pine in every conceivable combination with its associates. Average species composition of timber stands in the northern, central and southern portions of the type and of the region as a whole are given in table 1. As shown, there are certain geographic trends. Western larch, for example, is more abundant in the northern than in the central and southern portions. Western hemlock practically disappears from the southern part of the type but is common in the central and northern areas. Western red cedar, though found throughout the type, is rather local in its distribution being primarily confined to river flats, benches, and moist north slopes. Ponderosa pine though of importance within the general region embraced by the western white pine type is essentially a border species seldom associating with white pine in the type proper.

Of the six species commonly associated in the type, only western white pine and western red cedar are of sufficient value to log extensively under existing market conditions. White pine is of outstanding importance because of the large volume of the species--it comprises nearly half the merchantable volume of the type--and its high value. The lumbering industry of the Inland Empire is largely built around white pine. Engelmann spruce, Douglas fir, western larch, and lowland white fir logs seldom have a market value sufficient to pay the cost of logging, and consequently are logged to a limited extent. Western hemlock has practically no stumpage value. Hemlock and white fir tend to be heavily defective in mature and overmature stands, often making their presence a definite liability. Disposal of large volumes of low-value or totally unmerchantable timber, often necessary to apply desirable silvicultural measures, is a major management problem in the type. Economic and silvicultural objectives are often in direct conflict and the exigency of the former frequently dominates silvicultural considerations.

Figure 1.-- The western white pine region

Table 1.--Species composition of timber stands in the western white pine region

Species	Second-growth stands 1/				Mature stands western white pine region as a whole 2/
	Northern portion (North of Clark's Fork River)	Central portion (Clark's Fork River to St. Joe-Clearwater Divide)	Southern portion (St. Joe-Clearwater Divide to Lochsa River)	Average	
	Percent	Percent	Percent	Percent	Percent
Western white pine	45	46	55	49	45
Western larch	24	10	7	14	8
Douglas fir	11	12	15	13	12
Lowland white fir	3	13	12	9	14
Western hemlock	5	7	1	4	3
Western red cedar	6	2	2	3	4
Engelmann spruce	2	2	1	2	4
Lodgepole pine	3	7	6	5	1
Ponderosa pine	1	1	1	1	9
Total	100	100	100	100	100

1/ Based upon comprehensive growth, yield, and stocking studies made in stands from 30 to 120 years old throughout the type as defined (stands containing 15 percent or more of western white pine by volume).

2/ Based upon Forest Survey check cruises aggregating nearly a billion board feet Scribner rule. These check cruises thoroughly sampled the western white pine region as a whole but were not confined to the type proper.

CLIMATE

The climate of the white pine region is characterized by a short summer season of scanty precipitation and low humidities with a high proportion of clear, hot, sunny days, and long winters with heavy snowfall and fairly low temperatures. The mean annual precipitation ranges from 28 to 50 inches. Much of this is received as snow, averaging 103 inches in depth and ranging from 48 inches at the southern border to 244 inches at the upper altitudinal limit as measured at 13 permanent weather stations. At most of these stations, snow lasts until about the end of April, with first snow appearing toward the end of October. Only about 15 percent of the total precipitation falls during the summer months of June, July, and August. Mean annual temperatures range from 41.7° F. to 50.0° F. Daily temperature fluctuations are from 34° to 42° in July and August and 12° to 19° in January. Summer temperatures of 90° to over 100°, and winter lows of -10° to -25° are common. Sudden drops from above-freezing to sub-zero temperatures occasionally cause widespread injury to forest foliage, resulting in diminution of growth and some mortality. Phenological observations have determined the growing season to be approximately from May to August, inclusive. During this period scanty precipitation, high temperatures, and low humidities accompanied by high evaporation rates often combine to produce critical conditions for the establishment of natural regeneration. The extension of the western white pine type at high elevations is limited by low temperatures, and at low elevations by insufficient moisture indicated by low precipitation-effectiveness indices. Indices of 110 or more for the year, or 11.5 or higher for the growing season, indicate climatic conditions favorable for the growth of western white pine.

SUSCEPTIBILITY TO INJURY

Fire, disease, and insects are the principal causes of injury in the western white pine type and have a direct bearing on natural regeneration. Fire causes heavy losses; the control problem is one of the most difficult in the country. It is also an important contributing factor in the incidence and spread of disease and insects. Fire colors every phase of management practice; methods of cutting, stand improvement measures, and slash disposal must be considered in relation to fire and frequently modified to conform with fire control requirements. Fire, by breaking up old climax forests mainly composed of cedar, hemlock, and white fir, is also largely responsible for the perpetuation of the western white pine type in its natural state. Disease causes some of the most difficult management problems. The problem of low-value species is intensified by their susceptibility to wood-rotting fungi. The

white pine blister rust threatens the very existence of western white pine as an important component of the type. Large sums have been and must yet be spent to control this disease. Forest insects exact an annual toll that varies from an unimportant loss to devastation, leaving the residual stand of insufficient value to log.

FACTORS AFFECTING NATURAL REGENERATION

SEED SUPPLY

Western white pine trees produce comparatively few cones; 40 cones per tree is considered a good crop; more than 100 cones per tree is infrequent. The number of seeds per cone varies with the size of cone and extent of insect depredations; 120 seeds per cone is a good average. Number of germinable seeds produced per tree depends on number of cones, seed per cone, and the proportion of germinable seeds. Trees bearing a good crop of 40 cones with 120 seeds per cone averaging 44 percent viable produce about 2,000 germinable seed per tree. This is an average figure for good crops, though individual trees have been known to bear as many as 7,300 germinable seeds.

Seed production is distinctly periodic; western white pine trees bear good crops on the average at 3- to 4-year intervals. Individual stands may differ widely in periodicity, depending upon a number of complexly interacting factors such as age and site. In one stand observed five good cone crops were produced in nine years; in another, not one good crop was produced in eight years.

Most western white pine seed is borne by vigorous, dominant or codominant trees with normal crowns. Good vigor trees bear from three to seven times as much seed as poor vigor trees. Good vigor trees are effective seed producers at diameters of 14 inches and larger breast high. Fair vigor trees consistently produce fewer and smaller cone crops than do good vigor trees of the same diameter and are not effective seed producers at diameters of less than about 20 inches. Poor vigor trees are ineffective seed producers at any diameter. White pine trees as young as 10 years have been known to produce germinable seed. Trees become effective seed producers at about 70 years; thereafter, seed production is more dependent on individual tree size and vigor than age.

Of the principal western white pine associates, western hemlock and western red cedar are outstandingly abundant seed producers. Although seed and seedling mortality are also high, these species, particularly hemlock, become established in large numbers under favorable conditions.

Seed dissemination of all species begins in latter August or early September. Western white pine is the earliest, about 15 percent being released by September 1 and 85 percent by the end of October. Western larch, Douglas fir, and lowland white fir disseminate their seed at about the same time, from 70 to 80 percent falling by the end of October. The heaviest seed fall of western hemlock and western red cedar is in October and 40 to 50 percent falls in the late fall and winter.

About 90 percent of western white pine seed falls within 400 feet of the parent tree. Dissemination over greater distances, though sometimes occurring, is not sufficient to be relied upon for natural regeneration.

Seed of all species is naturally stored in the duff in the fall and remains viable until the following spring. Western white pine is the only species whose seed remains viable in appreciable quantity longer than the normal overwinter period. About 25 percent is viable the second year after storage. About 1 percent remains viable after three years' storage and a few seeds may retain viability in the duff up to six years.

Sources of seed for natural regeneration are seed stored in the duff, seed coincidently produced at the time of logging or fire, and seed subsequently produced by the residual stand. All are important, but stored and coincident seed sources though sometimes sufficient cannot be relied upon for natural regeneration. The reason is not inadequate seed supply so much as heavy seed and seedling losses. Insects, squirrels, and the like may destroy the major proportion of any particular seed crop. Furthermore, unfavorable conditions for germination and early survival may prevent any large numbers of seedlings from becoming established in a given year or even group of two or three years despite a plentiful seed supply. For these reasons, scattered seed trees, or some other form of continuing seed source such as adjacent uncut timber, etc., are necessary for consistently adequate natural regeneration.

GERMINATION

Germination begins in April or early May at low elevations and on exposed sites but is a month or more later at higher elevations and on protected sites such as north slopes where snow lingers late. Germination is practically over by July 1 on exposed sites and by August 1 to 15 on protected sites. Germination is markedly affected by the character of the surface-soil material. Mineral and burnt mineral surfaces are best for all species. Duff surfaces dry out rapidly and on exposed sites are a poor

germinating medium for all species. On sheltered sites, the larger-seeded species, western white pine, Douglas fir, and lowland white fir, germinate nearly as well on duff as on any other surface. Western larch, western hemlock, and western red cedar never germinate well on duff surfaces. Germination is good on rotten wood, but survival poor as this surface also dries out rapidly.

SEEDLING ESTABLISHMENT

The first season is of critical importance in seedling establishment as nearly 50 percent of all seedlings die in the first season. Losses drop off rapidly after the first year, and seedlings more than two years old are fairly well established. Studies of mortality causes during the critical first year show that early season losses are due principally to biotic agents. Of these, damping-off fungi are the most important. Fungi losses are irregular, however, and consistent differences between species or habitats have not been established. Insects, rodents, and birds may cause serious though unpredictable seedling losses.

As the season advances and the soil begins to dry, biotic losses largely cease and mortality thereafter is caused principally by physical agents. Insolation, causing high surface-soil temperatures, is the most important physical cause of mortality on exposed sites. Surface temperatures of 120° F. may cause injury to first-year seedlings; over 135° injury and death are common; and over 150° few seedlings survive. Lethal surface-soil temperatures are common during the summer months on the more exposed sites as soon as the surface soil begins to dry. Temperatures are highest on duff, making this surface especially hazardous on exposed sites. Temperatures are somewhat higher on burnt mineral surfaces than on natural mineral due to better heat absorption by the blackened surface. Under shade or on sheltered sites, surface-soil temperatures are less important and under fairly dense shade or on north slopes are not a cause of mortality. Western white pine, lowland white fir, and Douglas fir are the most resistant to heat injury, western larch is intermediate, and western hemlock and western red cedar are relatively susceptible.

Drought mortality is directly governed by the relation between soil moisture and initial root penetration. This relation is diagrammatically illustrated in figure 2. If seedlings can extend their root systems in pace with receding soil moisture as the season advances, drought mortality will not be important. Deep initial root penetration of western white pine, western larch, Douglas fir, and lowland white fir on exposed habitats makes these

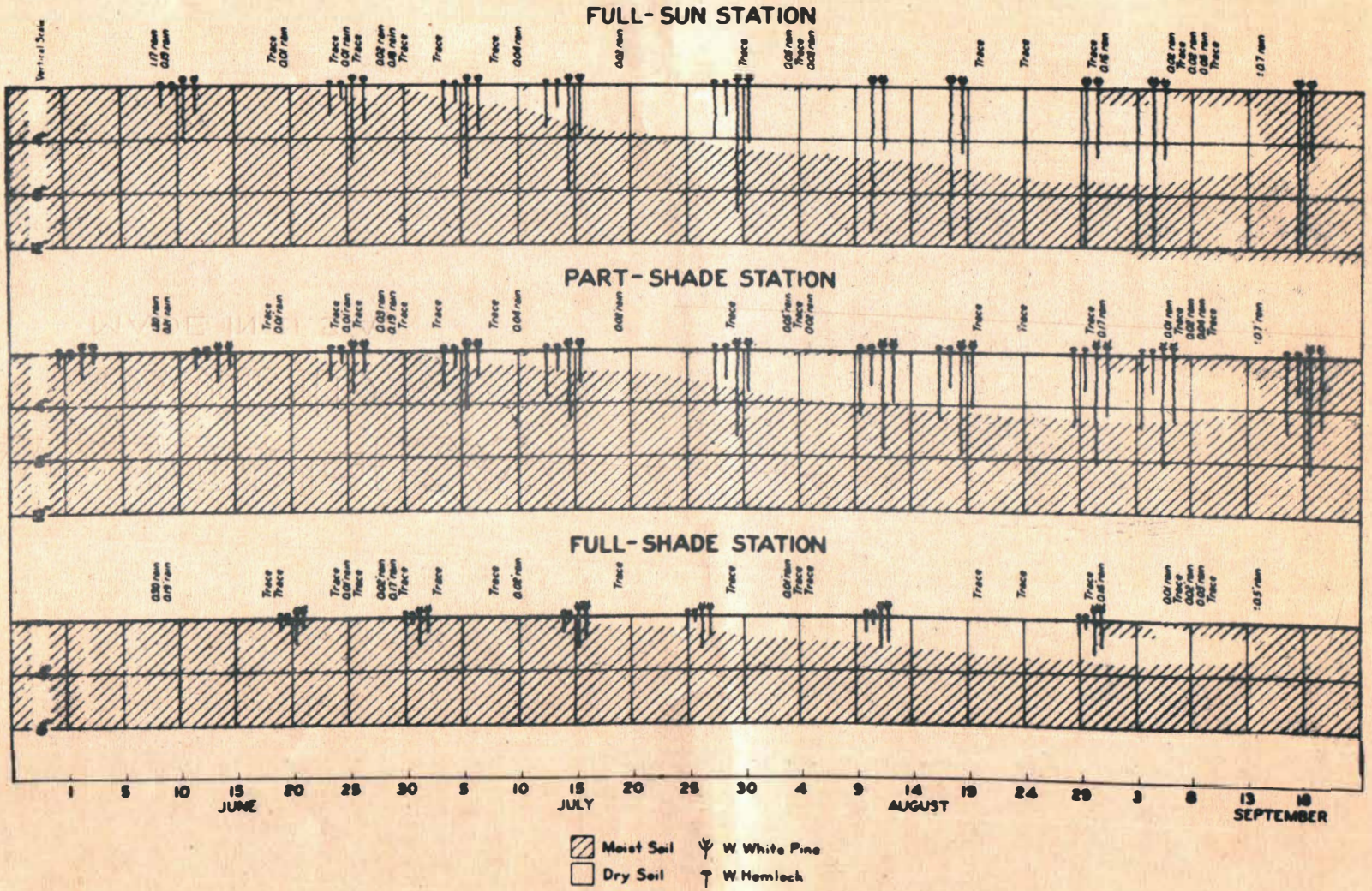

Figure 2.-- Root Penetration and progressive soil drying

species drought resistant despite early drying of the surface soil, while shorter-rooted western hemlock and western red cedar suffer heavily. On shaded, cool, and relatively moist habitats, drought is paradoxically the most important physical cause of mortality. Initial root penetration of all species is slower on such habitats and even shallow drying of the surface soil may cause drought mortality despite ample soil moisture at deeper levels.

All factors considered, seedling establishment of all species on severe to moderately severe sites is best under part shade. On more sheltered sites such as north slopes, light shade or clear-cut conditions are best. Western white pine, western larch, Douglas fir, and lowland white fir are resistant species with western hemlock and western red cedar relatively susceptible to initial mortality.

EARLY DEVELOPMENT

The problems of natural regeneration do not end with successful seedling establishment. Seedling stands may originate under conditions unfavorable to satisfactory subsequent growth and to only a limited extent can the species composition of the seedling stand be controlled by manipulation of the seed source. Following establishment, which for all species is best under moderate shade, requirements of individual species for best subsequent growth differ widely. On exposed sites, intolerant lodgepole pine and western larch make best development under full-sun conditions, where they make the most rapid initial growth of any species in the type. On such sites western white pine, Douglas fir, and lowland white fir, though also hardy, are benefited by a moderate amount of overhead shade during the early years of stand development. On protected sites, however, these three species make best growth under clear-cut conditions. Tolerant western hemlock and western red cedar require shade for best development even on relatively protected sites and can exist for long periods under dense shade. These species, together with lowland white fir which is also relatively tolerant, make better development than western white pine and other less tolerant associates under moderately dense shade.

This period of early development is of especial importance to the silviculturist. During this period, by regulation of the overwood density, accomplished by timely removal of the parent stand, and the application of inexpensive cultural measures to the reproduction stand such as weedings or cleanings, growth conditions and species composition can be more effectively improved and controlled than at any other time in the life of the stand.

REGENERATION METHODS

The silvicultural history of the western white pine type has been varied and colorful during the 30 years since cutting was first begun. Diversity of forest conditions, gradual accumulation of specific silvical information over the years, and pressure of economic considerations have led to the application of several regeneration methods. Clear-cutting, seed-tree, shelterwood, and a form of economic selection have all been tried although cutting has not been continued long enough in the type for any method to have been fully tested. This is especially true of areas cut on the shelterwood or selective plan as in few instances has sufficient time elapsed for more than the first cut of the series to have been made. Observations made on many cut-over areas, together with specific information on factors affecting natural regeneration gained from intensive research have, however, furnished some basis for an appraisal of regeneration applicable in the western white pine type. A comparative analysis of regeneration methods is given in table 2.

No one regeneration method can be recommended to the exclusion of all others. Based on present knowledge, clear-cutting, seed-tree, and shelterwood methods all have a permanent place in the management of the western white pine type. Forest conditions are too diverse and the necessity for compromise between silvicultural and economic objectives too pressing for any one method to suffice. Rather, a choice of methods is indicated, selection of the particular method to use on a given area to be made only after careful and rational appraisal of pertinent economic and silvicultural factors.

CLEAR-CUTTING

Clear-cutting was practiced to some extent on both the Kaniksu and Coeur d'Alene National Forests between 1909 and 1912, but was not continued principally because of difficulty in controlling the hot fires resulting from the broadcast burning of the slash. Although some of these early cuttings failed to reproduce, mainly because the areas clear-cut were too large or situated on exposed sites, there were some notable successes especially on the Coeur d'Alene Forest where the areas were smaller and more favorably situated. These successes, together with increased skill, experience, and confidence in controlled burning, have stimulated renewed interest in clear-cutting and since about 1929 it has been reapplied to some extent.

Table 2.--Comparison of regeneration methods applied in the western white pine type

	Clear-cutting	Seed-tree	Shelterwood	Selection
Form of forest produced.	Even-aged.	Even-aged.	Even-aged or of not more than two or three age classes.	Uneven-aged.
Seed source.	Nearby uncut trees and seed in the duff at the time of cutting. Seed in the duff seldom sufficient for satisfactory natural regeneration. Seed supply is usually ample if clear-cut areas are not more than about 400 feet across. Large clear-cut areas usually must be planted.	Selected seed trees. Only enough trees reserved to produce the quantity of seed estimated as necessary to adequately regenerate the area. From two to six white pine seed trees per acre are usually reserved and in addition a few trees of other species.	Reserved trees which are sufficiently numerous to insure an ample seed supply.	Reserved trees producing an abundance of seed.
Class of trees left after cutting.	None left.	Thrifty, vigorous, full-crowned dominant or codominant trees, principally western white pine, selected for their seed productivity and windfirmness. Seed trees are merchantable at the time of cutting, usually being from 16 to 24 inches in breast height diameter.	1. Selected seed trees of the same, or somewhat greater number left in seed tree cutting. Principally western white pine. 2. Thrifty, vigorous trees of merchantable species but below the lower diameter limit of merchantability. 3. Sound trees of species unmerchantable at time of cutting but that later may become merchantable.	All trees not selected as economically and silviculturally desirable for immediate cutting. Residual stand made of both merchantable and unmerchantable trees.
Abundance and species of reproduction usually resulting.	Good reproduction of white pine, Douglas fir, larch, and white fir where seed source is ample. Reproduction of hemlock and cedar relatively poor except on favorable sites.	Good reproduction of white pine, larch, white fir, and Douglas fir. Hemlock and cedar sparse except on aspects favorable to these species, as most north slopes.	Good reproduction of all species common in the type except larch. Hemlock, white fir, and cedar reproduce very abundantly under a shelterwood.	Reproduction abundant but principally of hemlock, white fir, and cedar.
Kind of stand in which best applied.	1. Even-aged stands principally composed of merchantable trees. 2. Defective, overmature stands only a small portion of which is or ever will be merchantable. Old stands consisting largely of defective hemlock and white fir are a common example.	Even-aged stands principally composed of merchantable trees. Stands from 120 to 200 years of age largely dominated by mature white pine are good examples.	1. Well-stocked stands with a large number of trees of merchantable species below the lower diameter limit of merchantability. 2. Stands containing a considerable number of sound trees of species unmerchantable at the time of cutting but that subsequently may become merchantable.	Limited application. Partial application possible in irregular, rather uneven-aged stands containing advance reproduction and immature trees, especially cedar, in addition to trees of merchantable size. In such stands, one or two selection cuttings can often be made to advantage, even though it may not be possible to permanently continue on a selection basis.
Aspects best suited to system.	North, east, and the less sheltered exposed west slopes. On these aspects white pine usually makes relatively better growth in the open than its principal competitors hemlock and white fir.	North and east slopes and the less exposed west slopes and flats.	Any aspect, though on north and east slopes the shelterwood must be sparse to get reproduction of desirable composition.	Any aspect, though on north and east slopes reproduction is likely to be sparse.
Number of cuttings required and length of regenerative period.	One cutting. Regeneration period usually one to ten years. Regeneration of adjacent areas, if left uncut to produce seed, will be delayed until a second cut is made.	One major cutting. Seed trees may be removed by a second cutting if economically practicable. If left uncut, few are likely to survive until the new stand is cut. Regeneration period one to ten years.	Minimum of two cuttings; a seed and a removal cutting. May be three or more cuttings in intensive application. Regeneration period variable, from one to forty years, depending on number of cuttings.	An indefinite number of cuttings. Regeneration more or less continuous.
Economic considerations.	Clear-cutting usually followed by broadcast burning is the cheapest method of restoring to productivity areas supporting large volumes of defective timber. Use of method often necessary to effectively abate high fire hazards. A wasteful method where considerable volumes of sound but unmerchantable timber are present.	Expensive and wasteful method on areas supporting a large volume of defective or unmerchantable timber as much stand improvement work is necessary to remove all but desirable seed trees. Reservation of suitable and usually highly merchantable seed trees necessitates an investment of about $10 per acre.	Reservation of merchantable trees for a second cut necessary. Disposal of unmerchantable and defective timber by pile-and-burn methods necessary at either first or second cut. As applied, most sound but unmerchantable timber is left for the second cut in hope that it may then be merchantable.	Method economically desirable but difficulty of maintaining stands of desirable composition and rate of growth greatly limits its application.

Clear-cutting, either in strips from 200 to 400 feet wide or in small irregular patches is a method well adapted for the natural reproduction of stands containing a high proportion of western white pine on the less exposed sites. It is not a good method on severe sites. Best application is in even-aged stands of merchantable timber fully ripe for cutting, or in overmature stands containing large volumes of defective and unmerchantable timber. It is a wasteful method where considerable volumes of sound but unmerchantable timber are present that may become merchantable in the future. Clear-cutting often can be combined advantageously with seed-tree or shelterwood methods.

SEED-TREE

The seed-tree method, consisting of clear-cutting with the reservation of selected seed trees, has been extensively employed on Forest Service timber sales. It should be pointed out, however, that although the seed-tree type of cutting, with some modifications, has been the principal National Forest regeneration method since about 1916, many stands cut over under the seed-tree marking rules are in reality shelterwoods because many trees other than the selected white pine seed trees often remain after cutting. The seed-tree method is well suited for the regeneration of western white pine stands, particularly on more sheltered aspects, and is a dependable method. It permits the removal by a single cutting of a maximum volume of timber over extensive areas. Best application is in even-aged stands principally consisting of mature western white pine. It is an expensive and wasteful method to apply in stands containing large volumes of unmerchantable timber, as disposal of much such timber is necessary to reduce the residual stand to desired seed trees. Under most conditions from two to six well-spaced western white pine seed trees, together with a few trees of other species, are sufficient. Western white pine trees selected for seeding purposes should be not less than 14 inches and preferably over 16 inches in diameter breast high, dominant or codominant in crown class, of good vigor, and with well-formed, normal crowns. Western white pine is relatively windfirm, and losses do not average more than 5 to 10 percent over a 10- to 20-year period. A second cut to remove seed trees is desirable utilization but not essential silviculturally.

SHELTERWOOD

Probably the majority of cuttings in the western white pine type have left residual stands of the shelterwood type, though relatively few have been definitely intended as such. Selective logging usually leaves residual stands of the shelterwood type. The shelterwood method consists essentially of removing the parent stand by a series of cuts, with a minimum of two, reproduction becoming established under the shelter of the parent stand. Most partial cuttings sufficiently heavy to permit establishment of reproduction but leaving more than a seed-tree stand can be classed as shelterwoods. In few instances, however, has sufficient time elapsed since the first cut to necessitate the second or removal cut, and in still fewer instances has the second cut been made. All of the principal species in the type reproduce readily under a shelterwood with the exception of western larch on more sheltered sites. The proportion of western white pine is usually not as high as that obtained by the seed-tree or clear-cut method, but through early application of cleanings and timely removal of the residual overwood, unsatisfactory composition and conditions for growth can be effectively corrected. The method is especially suitable in thrifty, well-stocked stands containing trees of desirable species of sub-merchantable size that can be advantageously left for a second cut. It does not give good results where the residual stand left after the first cut consists principally of trees not worth logging as often happens in selective logging. Composition of the reproduction stand is then usually poor, and the difficult problem of disposing of unmerchantable trees is passed to the future.

SELECTION

Although a number of cuttings have been made resembling a selection type of cutting, it cannot be said that the selection method actually has been applied in the western white pine type as the time elapsed since the inception of cutting has been insufficient to really test the method. Selection, not to be confused with selective logging, offers relatively limited possibilities. Western white pine, although it will reproduce after a fashion, will not make satisfactory subsequent growth under the shade of a continuing and fairly dense residual stand characteristic of the selection method. Selection cutting tends to favor the development of the more tolerant species which, with the exception of western red cedar, are the least valuable.